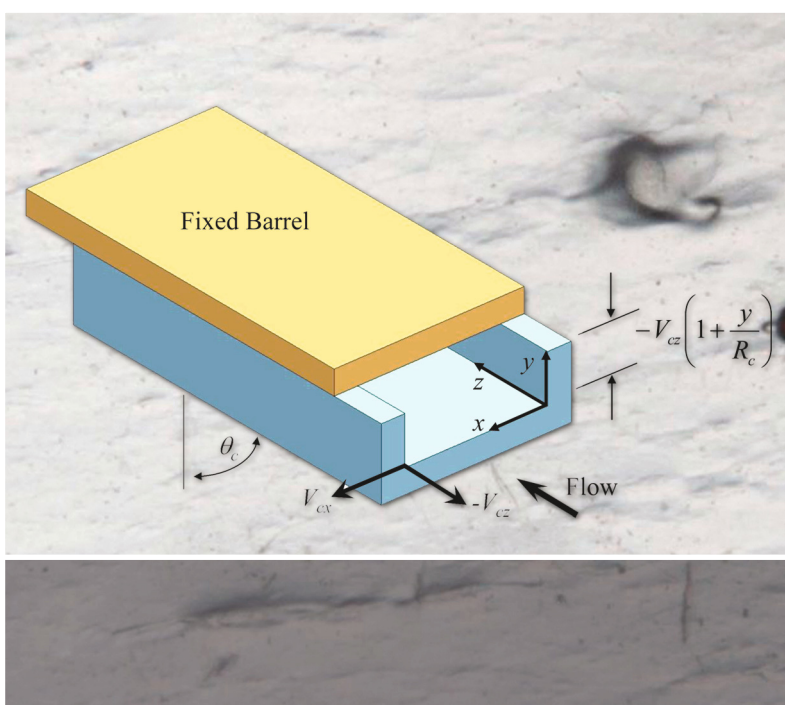


Gregory A. Campbell  
Mark A. Spalding

# Analyzing and Troubleshooting Single-Screw Extruders



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# Preface

Classically, all prior extrusion books are based on barrel rotation physics. Literature developed over the past 15 years has led to this first book to be published based on the actual physics of the process—screw rotation physics. After the theories and the math models are developed in the first nine chapters, the models are then used to solve actual commercial problems in the remainder of the book. Realistic case studies are unique in that they describe the problem as viewed by the plant engineers and provide the actual dimensions of the screws. Knowledge is developed using a series of hypotheses that are developed and then tested, which allows a series of technical solutions. Several actual solutions are proposed with the final results that solve the problem then clearly presented. Overall, there is not a book on the market with this level of detail and disclosure. New knowledge in this book will be highly useful for production engineers, technical service engineers working with customers, consultants specializing in troubleshooting and process design, and process researchers and designers that are responsible for processes that run at maximum rates and maximum profitability.

Debugging and troubleshooting single-screw extruders is an important skill set for plant engineers since all machines will eventually have a deterioration in their performance or a catastrophic failure. Original design performance must be restored as quickly as possible to mitigate production losses. With troubleshooting knowledge and a fundamental understanding of the process, the performance of the extruder can be restored in a relatively short time, minimizing the economic loss to the plant. Common root causes and their detection are provided. Hypothesis testing is outlined in Chapter 10 and is used throughout the troubleshooting chapters to identify the root causes. Elimination of the root cause is provided by offering the equipment owner several technical solutions, allowing the owner to choose the level of risk associated with the process modification. Mechanical failures are also common with single-screw extruders, and the common problems are identified. Illustrations are provided with the problems along with many numerical simulations of the case studies. Collectively, these instruct the reader on how to determine and solve many common extrusion problems. About 100 case studies and defects are identified in the book with acceptable technical solutions. Lastly, we

hope that this book provides the information and technology that is required for the understanding, operation, and troubleshooting of single-screw extruders.

*Gregory A. Campbell*

*Mark A. Spalding*

The views and opinions expressed in this book are solely those of the authors and contributors. These views and opinions do not necessarily reflect the views and opinions of any affiliated individuals, companies, or trade associations.

# Acknowledgements

My interest in fundamental polymer research began in 1964 when I began my graduate career. My research efforts were strongly influenced by my mentor Professor Edward G. Bobalek, one of finest gentleman and innovative research minds I have ever met. My research philosophy was strongly influenced by many encounters with Ed before and after I defended my dissertation. One particularly important encounter occurred when I was lamenting that my dissertation research did not appear to be a really important breakthrough. He took a long draw on his ever present pipe and said “Greg, that is why we call it research and not search.” From that time on I have always looked at my efforts as learning from the previous researchers that have laid the technical foundation in the area that is now being addressed. My role is thus to continue to build on that foundation when looking for a solution to the research challenge that I am currently addressing.

After leaving the University of Maine, I worked with wonderful groups of exceptional researchers at General Motors research, Mobil Chemical research, and Clarkson University. Many of these individuals spent their valuable time to help me hone my research skills. Probably the most influential individual was Dr. William Meluch; a true genius that I had the pleasure of working with for 13 years. Another good friend that had a major influence on my manner of approaching engineering research was Professor Art Fricke whom I collaborated with at the University of Maine and the University of Florida. My colleague Dr. Don Rassmussen at Clarkson University provided important guidance in all things thermodynamic.

My extrusion experience started when I directed process research at Mobil Chemical Research in the early 1980s. We developed and analyzed data on a 24 to 1 single-screw extruder with 12 infrared probes and 12 pressure probes using high-speed data acquisition. I then changed career paths and accepted a position at Clarkson University teaching chemical engineering while developing the Clarkson Polymer Processing Laboratory. The new concepts developed in this book were first recognized by Dr. Paul Sweeney when he was a graduate student in about 1988. I have to admit that it took considerable effort on Paul's part to convince me to even address these new concepts. Once we became convinced that it was important to complete the solution of the single-screw extruder analysis and bring the solution



back to the laboratory frame, it has taken 25 years to reach our current incomplete understanding. I would not have been able to acquire this understanding without the dedication and efforts of my colleagues and students that led the extrusion research in my lab: Paul Sweeney, Jeff Felton, Douglas Small, ChiCheng Wang, Don-tula Narasimharao, Diana Hunt, Hongying Cheng, Zirong Tang, Mary Ann te-Riele, Jason C. Baird, Sirisha Bomma, and Sam St. John. An academic without excellent students is severely handicapped and I can truly say that I was not handicapped.

The development of this book has been an interesting and exhausting “trip” which in all likelihood would not have been completed without the encouragement and understanding of Sue, my wife for the past 50 years.

*Gregory A. Campbell, Castle Research, Jonesport, Maine*

My extrusion career started as one of the founding members of the Polymer Processing Technology Team of The Dow Chemical Company in 1987. The team was built and led by Dr. Kun Sup Hyun and consisted of four members (along with Joseph Dooley and Thomas McCullough). During the early years, the team researched many aspects of polymer processing including single-screw extrusion, twin-screw extrusion, and die technologies. These early years allowed the team to develop strong skills in process fundamentals, design, and troubleshooting. I am grateful to have this experience and the opportunity to develop this skill set. I am also grateful for the many mentors that I have had through my life including my father, Robert Bean, Gene Kratzman, Prof. Lyle F. Albright, and Dr. Hyun.

A book like this would not be possible without the help and contributions from coworkers, industry experts, and family. Many of the figures were contributed by industry experts and their names are provided with the figure. Photographs, content, and assistance were provided by Timothy W. Womer (consultant), Jeffery Kuhlman (Glycon), Jeff Myers (Robert Barr, Inc.), James Fogharty (Plastics Engineering Associates Licensing, Inc.), John Christiano (Davis-Standard), William Kramer (American Kuhne), and many others. Numerous diagrams were made and enhanced by my sons Stephen W. Spalding and Aaron F. Spalding. I also thank those who reviewed the original chapter drafts.

My wife Pamela has been a source of inspiration and motivation during this project. I thank her and my sons for their continued support through the writing of this book. My parents William and Joan provided me with a loving environment while growing up, and they provided the foundation for success.

*Mark A. Spalding, The Dow Chemical Company, Midland, MI*

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